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# REPORT DOCUMENTATION PAGE

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A New Approach to Structural Reliability in Fatigue Failure

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6. AUTHOR(S)
Dr. Sia Nemat-Nasser (PI)
Dr. Joseph Zarka

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7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(ES)
University of California, San Diego
Dept. of AMES
9500 Gilman Drive
La Jolla, CA 92093-0416

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9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
Program Officer Roshdy S. Barsoum ONR 334
Ballston Centre Tower One
800 North Quincy Street, Arlington, VA 22217-5660

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The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

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13. ABSTRACT *(Maximum 200 words)*

The project objective is to develop formalism for assessing fatigue fracture of welded parts of ship structures based on a newly developed automatic **L**earning **E**xpert **S**ystem (**L.E.S.**), using extensive knowledge of material characteristics, experimental results, and results obtained through computational simulations. Any study of the welds on a ship structure must take into account the uncertainties and random characteristics of the loading, as well as the fatigue lifetime of the welds. Due to the stochastic nature of the loads, the available deterministic approaches are not sufficient to give a reliable evaluation of the structural safety. Although there has been some effort to fill this gap by probabilistic approaches, these are yet of limited usefulness because of the limited available databases. The research project will ultimately demonstrate the applicability and effectiveness of **L.E.S** to this class of engineering mechanics problems.

As the first and fundamental step in this project, it is necessary to build a relevant database. Experimental and field date has secured from Navy research centers, and through collaboration with scientists working in this general area. Additional data has been obtained from literature searches.

14. SUBJECT TERMS
structural reliability, fatigue failure, welded structures

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REPORT DOCUMENTATION PAGE (SF298)
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# INTERIM PROGRESS REPORT

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| **ONR Grant Number:** | N00014-96-1-0631 |
| **Period Covered by Report:** | April 1, 1996 - March 31, 1997 |
| **Title of Proposal:** | *A New Approach to Structural Reliability in Fatigue Failure* |
| **MOD Number:** | P00001 |
| **PR Number:** | 97PR01513-00 |
| **Authors of Report:** | Dr. S. Nemat-Nasser (PI) and Dr. Joseph Zarka |

## I. SCIENTIFIC AND TECHNICAL PERSONNEL SUPPORTED BY THIS PROJECT AND DEGREES AWARDED DURING THIS REPORTING PERIOD

*Scientific and Technical Personnel:*

**Masoud Beizaie** (Staff Research Associate): research focusing on the reliability of weldments, especially those used in marine structures. This activity includes extensive literature survey and search for available databases and software.

**Joseph Zarka** (Visiting Research Scientist from Ecole Polytechnique, France): the research project includes collaboration with Dr. Zarka, who spends at least three months each research year at CEAM of UCSD. The approach, to study the reliability of ship structures and particularly their welded parts, utilizing the automatic **L**earning **E**xpert **S**ystem (**L.E.S**), has been developed by Dr. Zarka.

*Graduate Research Assistants:*

**Jun Huang** (9/96 - present): research focusing on fatigue and Dr. Zarka's new approach to inelastic analysis and the use of numerical analysis software. The research on fatigue includes examination of micro-mechanisms of fatigue, the influence of non-zero mean stress, the accumulative damage theories and the use of statistics in fatigue. The main idea of the new approach is to solve the plastic problem using elasticity solutions. Extensive comparative analysis has been done utilizing the basic components of NISA.

## II. BRIEF OUTLINE OF RESEARCH FINDINGS FOR THIS REPORTING PERIOD

A general review of structural fatigue has been accomplished through extensive literature research of the most recent papers on this subject. Special attention has been given to fatigue damage of structures subjected to complex random time-varying loads, for which some researchers[1] have proposed to use the theory of random processes and consider frequently one-dimensional random loading.

At first, it is necessary to simulate an ensemble of stress-time histories from an ergodic process. Then, employing a cycle identification technique (very often the rain-flow method), and a

damage accumulation model (very often the linear Palmgreen-Miner rule), one obtains the fatigue damage for the simulated time history and subsequently the structural fatigue life.

Currently, we are utilizing two important papers: "Stochastic Fatigue Damage Accumulation Under Broadband Loadings," D.P. Kihl, S. Sarkani, and J.E. Beach, *Int. J. Fatigue,* (1995), and "Feasibility of Auto-regression Simulation Model for Fatigue Studies," S. Sarkani, *J. of Struc. Engr.* (1990). These papers provide us with the best actual representations of random loadings and with several experimental results. Our objective is to cast their test interpretations into our proposed new framework.

## III. OTHER ACTIVITIES

An intensive Workshop "New Approach to Inelastic Analysis of Structures" was conducted March 24-28, 1997, at UCSD's CEAM, La Jolla, CA. The Workshop was taught by Dr. J. Zarka (workshop coordinator)and Dr.'s J. Frelat, P. Navidi and M. Min-Hui Yu from the Laboratoire de Mécanique des Solides, Ecole Polytechnique, France. The workshop was attended by eleven participants; post-doc's and graduate students from UCSD's CEAM, IMM, and AMES department.

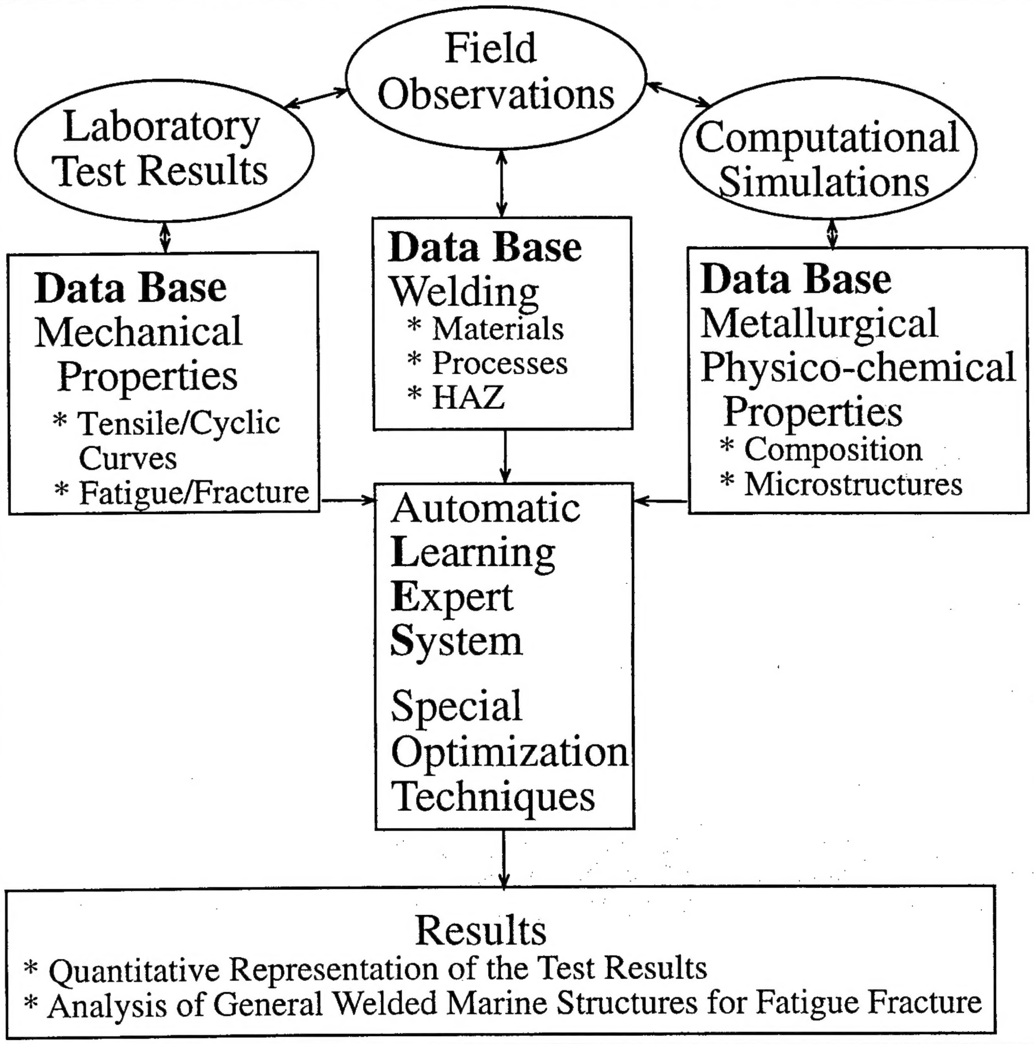
*The Aim of the Workshop:* The designers of structural systems often have to take into account the inelastic behavior of their materials, involving work-hardening and creep. For this, the classical mathematical theory of plasticity has been used over the past several decades. Many contributors have helped to provide correct formulations and useful tools to solve technologically important problems. Such formulations are usually given in terms of rates or increments of the field quantities with unilateral constraints, and require long and expensive computer calculations. In such formulations, it is necessary to define a stress field which is statically and plastically admissible throughout the entire structure.

A new approach has been proposed in the Laboratoire de Mécanique des Solides of the Ecole Polytechnique (France). This approach is based on the introduction of a change of variable, leading to an efficient method to calculate bounds on the response of the structure. The method can be implemented using ***quasi-static elastic analysis,*** even for dynamic loadings of the structure. The method dramatically decreases the amount of time required for the complex inelastic analysis, even during dynamic loadings, such as seismic or contact-rolling loadings.

The purpose of this intensive Workshop is to show how it is possible to transform the classical formulations to make them much clearer, leading to easier and more direct solution of the problems. This transformation involves two fundamental steps: i) ***the constitutive modeling of materials***, based on continuum mechanics, and ii) ***the numerical treatment of structures*** made of such materials, involving solution of the global associated boundary-value problems.

The participants were provided with a thorough grounding in this new approach. This will be achieved through a balance of lectures, demonstrations and discussions of problems of the students own interest.

# New Approach to Structural Reliability in Fatigue Failure




## Objectives

Development of Systematic Reliable Procedures for Assessing Fatigue/ Fracture of Welded Structures, with Other Broad Applications

## Current Status

Data Collection/Literature Search
Development of Computational Tools
* Simplified Stress Analysis
* Classical Fatigue & Reliability Analysis
* Automatic Learning & Optimization

Most of the Results by End of 2nd Year

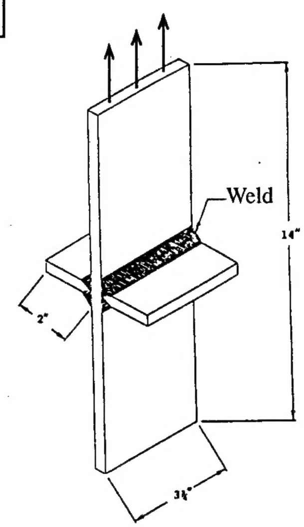



Figure from D.P. Kihl, Naval Surface Warfare Center (Nov. 1994)